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GAS DISCHARGE TYPE DISPLAY PANEL AND ITS MANUFACTURING METHOD

BACKGROUND OF THE INVENTION

This invention relates to a gas discharge type display panel such as a plasma display panel, and its manufacturing method.

A prior art on the production processes of a gas discharge type display device, especially production processes from seal frit formation to sealing and exhausting is described in "FPD Intelligence" magazine (June number, 1998) pages 84 through 88, for example. The description at page 86 shows the necessity of selecting exhaust not more than the softening point a sealing glass.

Also, in a method of manufacturing a gas discharge type display panel such as a plasma display panel, it is necessary for exhausting the inside of the panel in advance of the inclusion of discharge gas. To do this, in addition to the above-mentioned method of exhausting only the inside of the panel after the sealing, a method of exhausting the whole of a furnace during the sealing to exhaust the inside and outside of the panel at a time is also known. One example thereof is disclosed in Japanese Patent Prepublication No. 326572/1998.

SUMMARY OF THE INVENTION

In a gas discharge type display panel such as a plasma display panel, as sealing glass a material in paste form including an organic substance (binder) as an additive, which facilitates the application of glass frit is often used. This organic substance is burned during calcinations, sealing and exhausting processes and emitted into the outside of the panel as gas. However, small quantity of the gas unusually remaining

within the sealing glass after tip off may appear in the inside of the panel when the panel discharged. From the sealing glass, the gas involved at the time of sealing, in addition to the gas associated with the binder, leaks into the inside ofthe panel while discharging, which may contribute to the lowering of brightness when lighting the panel over an extended time period. The first object of the present invention is to provide a gas discharge type display panel which gives less amount of discharged gas from the sealing glass when discharging over an extended tie period and less lowering of brightness when lighting the panel over anextended time period.

There are such cases as the cross-sectional shape of the sealing glass worked between substrates at both the end face of the internal space side and the end face of the external side is a concave toward the internal of the sealing glass as shown in FIG. 4 (b), and, in contrast, as the cross-sectional shape at both end faces is a convex as shown in FIG. 4 (c), in which the size of the cross-sectional area parallel to the substrates varies widely. The exterior stress and the internal stress due to the difference in thermal expansion between the sealing glass and the distortion of the substrates are applied uniformly in the inside of the sealing glass. Owing to this, there is such a problem in the conventional gas charge type display panels that the portion having a small cross-sectional area, especially on the cross-sectional area of the sealing glass parallel to the substrates have a lower strength. The second object of the present invention is to provide a gas discharge type display panel having a high reliability in mechanical strength.

In the conventional manufacturing method for gas discharge type display panels such as plasma display panels, though an amorphous glass frit rather than a crystalline glass frit is typically used in considering the advantages in process temperature margin, the amorphous glass has such a characteristic as it is fused when

reheated after sealing. In the process of manufacturing the gas discharge type display panel, there may occurs accidentally such a case that the gas unnecessary for effective discharge remains inside the panel, for example, due to an absorption of moisture content or carbon dioxide gas on the MgO film of the protection layer of the plasma display panel display. Though the manufacturing method certainly applies a process for removing those gaseous impurities by exhausting the inside the pane in high temperature, if the seal frit might get soft in too high temperature due to inadequate temperature control and leak accidentally, the display operation is made disabled. Thus, in case of applying a amorphous glass frit to the seal frit of the gas discharge type display panel, the gas temperature for exhausting in high temperature has been selected to be no more than the temperature at the softening point for the seal frit. In terms of removing the gaseous impurities efficiently, it is preferable to use high temperature as much as possible for high-temperature exhaust operations.

As for another exhaust method, there is such a method that, after sealing the front substrate and the back substrate by fusing and fixing the conventional sealing glass, only the inside of the panel is made exhausted invacuum along with baking the inside the panel. In this method, in case that the distance between the front substrate and the back substrate is as small as several hundred m, it could takes several hours to exhaust the internal gas completely due to high exhaust conductance, and especially in case that the discharge areas are formed by closed cells separated by separation walls to each other, the complete exhausted state can not be established.

On the other hand, in the method that the whole of the furnace is exhausted in vacuum when sealing and the inside and outside of the panel is exhausted simultaneously, it is required to use the procedures including steps for exhausting the whole of the furnace itself or the vacuum chamber formed to be large enough to enclose

the panel at first, and then filling a larger quantity of discharge gas than the volume of the inside of the panel, which requires the upsizing of the manufacturing apparatus and reduces its productivity. The third object of the preset invention is to provide a structure the gas display type display panel and its manufacturing method which enables to establish a high efficiently in exhaust operations and reduce the remained gaseous impurities in the final product.

As the aforementioned pressurizing clip is used in high temperature, it should have heat resisting properties, which may be high-priced and may be damaged by repetitive use in the manufacturing process, or degraded for a designated clip pressure. In addition, for the gas discharge type display panels such as plasma display panels, though their plural substrates can be manufactured from a single glass plate as in the manufacturing of liquid crystal panels, evenin trying to forma single plate by sealing together at first, and then separate it into plural panels later, as it is difficult to apply a uniform load onto the connecting parts between the panels in the sealing process, there have been such a problem that special tools for pressurizing operations are required, leading to further upsizing in cost. The forth object of the present invention is to provide a manufacturing method which can use only the clips for temporary fixing and protecting displacement in order to apply pressure in sealing the front substrate and the back substrate and enables to seal plural panels simultaneously with higher yield rate.

The sealing operations are performed typically in the temperature range corresponding to the viscosity between 104 (working point) and 107.65 (softening point). The inventors of the present invention uses the seal frit formed by adding fillers to $PbO-B_2O_3$ system glasses, and they finds that there was not found any leakage or large scale displacement of the sealing glass toward the inside of the panel, and the sealing glass could be broken down to the thickness equivalent to the height of the

separation wall only by means of the difference in the pressure between the inside and outside of the panel without using any special pressurizing clip, even if the inside of the panel is exhausted in the temperature exceeding the temperature corresponding to the softening point and less than the temperature corresponding to the working point. In addition, they found that there are protruding portions having a curvature radius between 0.1 mm and 1mm, measured from the display surface, on the sealing glass over its internal space wholly. The aforementioned first embodiment can beattained by allowing the surface glass to have protruding portions having a curvature radius between 0.1 mm and 1mm, measured from the display surface, on the sealing glass over its internal space wholly.

The aforementioned second embodiment of the present invention can be attained by means that the shape of the cross-sectional area vertical to the substrate of the sealing glass and at both the end face of the internal space side and the end face of the external side is convex to the internal of the sealing glass at least at one part of the peripheral of the substrate.

Furthermore, as the exhaust operations are applied to the sealing glass having a clearance gap between the separation wall and the front substrate before the sealing glass is broken down when exhausting exhaust operations performed in the sealing process, the exhaust operations with high efficiency can be performed and the resultant concentration of gaseous impurities can be reduced. With this method, the exhaust operations can be smoothly for the gas discharge type display panel, in which the discharge space formed as cells separated by the separation walls, has more difficulty in exhausting operations than the gas discharge type display panel having a straightforward separation wall structure. By means that using two different kind of sealing glasses having different softening points, one sealing glass is sealed in lower

temperature at first, which is aimed to make the sealing glass having a higher softening point operate as a spacer and to exhaust the existing clearance gap between the separation wall ad the front substrate, and then, heating in a higher temperature in order to seal with the sealing glass having a highersoftening point, the temperature profile for sealing and exhausting operations may have higher freedom with respect to time and temperature, and consequently the exhausting operations with higher efficiency can be performed easily at the temperature rise phase. In addition, even in case that the exhaust operations are performed after sealing, the exhausting operations with higher efficiency can be performed by selecting the operation condition having the temperature range exceeding the softening point and no more than the working point, andconsequently the resultant concentration of the remained gaseous impurities can be reduced. The aforementioned third object of the present invention can be attained byexhausting the inside of the panel in the sealing process and by applying the exhausting operations in the temperature range exceeding the softening point and no more than the working point.

In case of using a sealing glass containing a filler, when the inside of the panel is exhausted in the sealing process, the filler is draw firmly toward the inside space and the average filler concentration from the end face of the internal space side to the range of 100 m may be 10% or more higher than the average filer concentration in the other part. In such a case, as the liquidity in the inside space can be reduced by collecting the filler in the inside space when sealing, the sealing glass does not move largely to the inside space even if the exhausting operations in higher temperature are applied later, the volume for the exhaust route can be effectively reserved. In this case, though there may arise unexpectedly such a problem that only the thermal expansion at the inside space becomes lower, as there are many concave and convex parts in the inside space in

a practical sense, and thus, the distortion due to the difference in the thermal expansion between the substrate and the inside space may be relaxed, this does not lead to such a severe problem as cracks and large-scale distortion for the whole panel.

In case of using V_2O_5-P_2O_5 system glasses having lower thermal expansion coefficient without filler to be added in stead of using PbO-B_2O_3 system glasses with filler added as a seal frit, as the liquidity at the high temperature becomes higher, the sealing glass move largely to the inside space and may leak accidentally. In order to prevent this problem, a glass layer having higher heat resistance than the sealing glass is made formed so as to be adjacent to the end face of the inside space or located within 2 mm from the end face in order to block the flow of the sealing glass. This glass layer may be formed by the material identical to the material used for the separation wall at the same time when the separation wall is formed, or formed by adding another seal frit round inside the inside space.

By exhausting when sealing, due to the pressure difference between the inside and outside of the panel, as described above, the sealing glass can be broken down to the thickness equivalent to the height of the separation walls without using the pressurizing clips. Also in case that two or more gas discharge type display panels are manufactured from a couple of substrates, the parts which can not sufficiently pressurized by the conventional pressurizing clips may be pressurized by exhausting at the same time when sealing, and thus, as the sealing can beestablishedwith higher yield rate independently upon the layout method of two or more gas discharge type display panels, which can attain the forth object of the present invention.

In case that the seal frit for sealing the substrates due to the pressure difference between the inside and outside of the panel, the seal frit made of crystalline glass frit (also including filler materials conditionally) may not be broken down completely if the

exhaust operations are performed before the viscosity of the material increases due to crystallization. Thus, as there is such a severe time condition for pressure reduction, it is preferable to use amorphous glass frit (also including filler materials conditionally) as the seal frit used for sealing the substrates.

As for the seal frit used for bonding the exhaust tube, by making the shape of the exhaust tube so as to allow the area of the bonding surface between the exhaust tube and the substrate to be large enough, there is no leakage problem in the exhaust operations in high temperature even if using an amorphous glass frit (also including filler materials conditionally) identical to the material used for sealing the substrate. However, by means that "an amorphous glass frit (also including filler materials conditionally) having higher softening point is used for bonding the exhaust pipe, and an amorphous glass frit (also including filler materials) having lower softening point is used for sealing the substrate", or "a crystalline glass frit (also including filler materials conditionally) having higher softening point is used for bonding the exhaust pipe, a crystalline glass frit (also including filler materials conditionally) having lower softening point is used for sealing the substrate, and then the exhaust operations are applied after completing the crystallization of the crystalline glass and fixing the exhaust tube", making the materials used for seal frits forbonding the exhaust tube have higher heat resistance than the materials for sealing the substrate, there is no problem for leakage from the bonding part of the exhaust tube independently upon the shape of the exhaust tube.

The exhaust tube is typically designed and manufactured so that the exhaust port may be connected to the end side of the bonding part to the substrate, and after the exhaust operations completed and the internal gas is completely exchanged, the exhaust pipe near the boding part to the substrate may be burned off for sealing. Alternatively,

by means that a glass component shaped in a short exhaust pipe is connected to the substrate, and that, without connecting an exhaust port connected to the glass component individually, a larger exhaust port is connected to the substrate and the exhaust operations are applied to the enclosure of the glass component, and then the glass component is heated for burning off. However, in case of using the glass component used exclusively for this way of sealing, the present invention can give an identical effect brought by the same method as described above.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a shape of the sealingpart of the plasma display panel of the first embodiment of the present invention.

FIG. 2 shows temperature profiles at the sealing and exhausting operations in the first embodiment.

FIG. 3 illustrates stepwise changes in the panel formation after the sealing process in the first embodiment.

FIG. 4 illustrates a shape of the sealing part of the plasma display panel in the prior art.

FIG. 5 shows a relationship between the lighting voltage and the time for the exhausting and aging operations in the first embodiment

FIG. 6 shows an exhaust route of the plasma display panel.

FIG. 7 shows a variation per hour in the brightness in the prior art and in the first embodiment

FIG. 8 shows temperature profiles at the sealing and exhausting operations in the second embodiment.

FIG. 9 shows a shape and a state of the sealing part of the plasma display

panel.

FIG. 10 shows a relationship between the lighting voltage and the time for the exhausting and aging operations in the first embodiment.

FIG. 11 illustrates a cross-sectional view showing the shape of the exhaust pipe 13.

FIG. 12 illustrates a cross-sectional view of the plasma display panels of the forth embodiment and the prior art.

FIG. 13 shows temperature profiles at the sealing and exhausting operations in the forth embodiment.

FIG. 14 shows a structure of the back substrate 2 of the firth embodiment.

FIG. 15 shows temperature profiles at the sealing and exhausting operations in the fifth embodiment.

FIG. 16 shows temperature profiles at the sealing and exhausting operations in the case 6 of the sixth embodiment.

FIG. 17 illustrates stepwise changes in the panel formation after the sealing process in the case 6 in the present invention.

PREFERRED EMBODIMENT OF THE INVENTION

(Embodiment 1)

Now, a manufacturing method for plasma display panels in the first embodiment of the present invention is described. In this embodiment, what is used is a sealing method in which the panel is sealed along with the exhaust operations, and the sealing glass is broken down by using the pressure difference between the inside and outside the panel. For comparison, a panel manufactured by the conventional sealing method in which the panel is pressurized by clips is studied.

In this embodiment, the patterns 14 for the sealing glass is formed by applying a dispense method to the back substrate 2, and then, the seal frit is formed by drying and removing the binders. An amorphous glass type seal frit (390° for softening point, 450° for working point and also including the filler materials) is used for the sealing glass 14.

Next, the processes after sealing and exhaust operations are described. In FIG. 2, a temperature profiles for sealing and exhaust operations are shown. FIG. 2 illustrates the temperature profiles of panels exhausting along with the sealing operation. The sealing and exhaust processes in the present invention include the heating-up process for increasing the temperature up to the sealing temperature (450°C) and the first heat insulation process for keeping the sealing temperature, the heat-down process for initiating the exhaust operation after the completion of the first heat insulation process and reducing the temperature down to the degasification temperature (430°C), the second heat insulation process for keeping the degasification temperature and the cooling down process for reducing the temperature down to the room temperature. In the conventional method, the sealing is completed from the heating-up process to the heating-down process along with pressurizing the face substrate 1 and the back substrate 2, and then, the exhaust operation is initiated and followed by the heat insulation process and the cooling down process.

FIG. 3 shows a stepwise change in the panel states in the exhausting operation along with the sealing operation.

(1) At fist, the locations of the front substrate 1 and the back substrate 2 finished by the above described processes are adjusted so that the display electrode and bus electrode, both formed at the front substrate 1, and the address electrode 10 formed at the back substrate 2 may be orthogonal to each other. The clip 17 is provided with weak clip force because it is not aimed to break down the sealing glass 14. Any

component other than clips may be applied as far as the component gives no displacement of the sealing glass. Placing the back substrate 2 at the upper side, the exhaust pipe 13 coated and burned with amorphous glass type seal frit 15 (including filler materials) is fixed above the exhaust hole by the anchor. The composite substrates are placed inside the furnace and an exhaust head is coupled to the exhaust pipe 13.

FIG. 3 (a) illustrates a panel configuration in which the panel to be exhausted when sealing is installed in the sealing furnace. For simple explanation, only the outline of the front substrate 1 and the back substrate 2 is shown, and the illustration of the clip 17 used for fixing temporarily the panel is also simplified. In addition, the anchor for fixing the exhaust pipe 13 is not shown.

The temperature is raised up to the sealing temperature, 430°C. FIG. 3 (b) shows the state of the sealing glass 14 immediately after the temperature reaches 430°C and the clearance gap between the front substrate 1 and the back substrate 2. The sealing glass 14 gets soft and contacts to the front substrate 1, and the air tightness of the periphery of the substrates can be maintained, but the clearance gap between the substrates does not reach the height of the separation wall 11 because there is not a pressurizing clip. The seal frit 15 used for bonding the exhaust pipe 13 and the back substrate 2 is not fully crystallized and stays in the state in which its viscosity is low.

(2) After the temperature reaches the sealing temperature, 430°C, the temperature is kept constant for 30 minutes. During this process, the seal frit 15 completes its crystallization, and the exhaust pipe 13 contacts firmly to the back substrate 2. At this state, the exhaust operations are initiated.

(3) The temperature is made reduced in parallel to the initiation of the exhaust operation. The pressured inside the panel reaches 10^{2} to 10^{-4} Torr in one or two minutes after starting the exhaust operation, and the sealing glass is broken down by the pressure

difference between the inside and outside the panel. FIG. 3 (c) shows the state of the sealing glass 14 after completing the break-down of the sealing glass and the clearance gap between the front substrate 1 and the back substrate 2.

(4) The temperature is kept constant at 350°C in the process for reducing the temperature while the exhaust operation continues, and the gas unnecessary for discharge operations is extracted. After cooling down to the room temperature, the discharge gas is led through the exhaust pipe 13 to the discharge space so as to make the pressure reach 300 Torr, and then the exhaust pipe 13 is burned off by localized heating, and finally the gas discharge type display apparatus is finished.

FIG. 1 shows the finished state of the sealing glass 14 between thesubstrates. FIG. 1 (a) shows the sealing glass 14 viewed in thedirection from the display panel, in which its width extends approximately to 5 mm and protruding parts with their curvature radius between 0.1 mm and 1 mm are observed over the entire perimeter of the discharge space. Though the protruding parts of the sealing glass 14 having larger volume, which are often observed when breaking down the sealing glass 14 by the pressurizing clips, extend largely by break-down operations and thus those parts seem to be shaped in protruding parts, their curvature radius is larger and their formation process and resultant shape is not different from the small-sized protruding parts in this embodiment. In addition the small-sized protruding parts in this embodiment are not formed incidentally, but formed bymeans that the sealing glass 14 is pulled toward the inside space when it gets soft, which are observed at the dispersed positions over the entire perimeter.

FIG. 1 (b) shows the state of the sealing glass 14 at the cross-section viewed vertically to the back substrate 2. The sealing glass 14 is broken down to the state in which its thickness reaches to the height of the separation wall 11, and the shape of its

inside end part is convex with respect to the discharge space and the shape of its outside end part is concave with respect to the discharge space. This can be interpreted in the following manner. In case that the exhaust operations are applied in the sealing process or at the temperature exceeding the softening point after the sealing process, as the sealing glass gets soft, the sealing glass ispulled back inside the panel However, for the viscosity at the temperature less than the working point, the sealing glass does not leak. Though the sealing glass near the substrate is not pulsed so much due to friction between the sealing glass and the substrate, the sealing glass near the center of the clearance gap between the substrates and located in the distance from the substrates tends to be pulled back inside the panel. Therefore, the shape of its inside end part is convex with respect to the discharge space and the shape of its outside end part is concave with respect to the discharge space.

FIG. 4 shows the finished state of the sealing glass 14 between thesubstrates formed by the conventional sealing method using clip pressurization for the comparison with this embodiment. FIG. 1 (a) shows the sealing glass 14 viewed in thedirection from the display panel, in whichthe shape of the sealing glass at the discharge space and at the outside is defined by smooth lines and curves. As for cross-sectional shape of the sealing glass 14 between the substrates, there are such a case shown in FIG. 4 (b) as shaped in a convex (humpbacked) surface at both the end face at the internal space and the end face at the outside, and there are also such a case shown in FIG. 4 (c) as shaped in a concave (double enveloping) surface contrarily. In general, the states of the sealing glass 14 at the cross-section viewed vertically to the back substrate 2 of the panel formed by the sealing method using the conventional clip pressurization are categorized into either one of those shown in FIGS. 4 (b) and (c). As those states includes a part having a small cross-sectional area parallel to the substrates, they are yield to the

tensile load developed in the direction in which the substrates are to be removed. As for the state shown in FIG. 4 (b), as all the contact angles of the sealing glass 14 with respect to the substrate are 90 degrees or more, this state is very weak also for the sheering stress. In contrast, the state of the sealing glass 14 at the cross-section viewed vertically to the back substrate 2 of the panel fabricated in association with this embodiment has no dispersion in the cross-sectional area parallel to the substrate as shown in FIG. 4 (b), which has a strong property against the tensile load developed in the direction in which the substrates are to be removed. As for the sheering stress, as this embodiment include a portion in which the contact angle of the sealing glass 14 with respect to the substrate are 90 degrees or more, this embodiment is not superior to the structure shown in FIG. 4 (c) but stronger than the structure shown in FIG. 4 (b).

Thus, by means that the internal end part is shaped so as to be convex with respect to the discharge space and the outer end part is shaped so as to be concave with respect to the discharge space, which is found in the panel fabricated in this embodiment, what can be obtained is such a gas discharge type display panel as has an enough strength with respect to the stress applied in various directions and provides a higher reliability in the mechanical strength. By means of introducing the inert gas when sealing rather than applying the exhausting operation, the cross-section at both the internal space end part and the external end part of the sealing glass 14 can be formed to be convex with respect to the internal space.

In order to study the effect of the exhausting operation initiated when sealing over the performance of the panel display, two types of panels are manufactured by varying the parameters Xh shown in FIG. 2 defined for the duration time forexhausting operation, and then their lighting voltage is measured. Those panels include a panel in this embodiment in which the exhausting operation isinitiated when sealing, and a

panel in the reference example in which the exhausting operation is initiated after breaking down the sealing glass 14. The measurement result is shown in FIG. 5 (a). In the example of plasma display panel, by applying the exhausting operation while keeping the high temperature, the protection layer, the fluorescent material, the water contained absorbed in the separation walls and the gaseous impurities like carbon dioxide gas are removed, and thus, the discharge operation is enabled at a lower voltage. However, when a designated time period passes on, the gas absorbed in the protection layer and such is not released outside, or it may be absorbed again immediately after it is released. For example, in case of the reference example shown in FIG. 5 (a), even if the exhaust operation continues for 6 hours or longer, the lighting voltage does not changes. In order to establish a stable driving characteristic with lower voltage for the gas discharge type display panel such as plasma display panel, it is the most preferable to maintain the exhausting operation for 6 hours even in this reference example. In this embodiment, the exhausting operation can be completed within 3.5 hours, and the light voltage can be reduced by 50V approximately. This is because a large amount of gaseous impurities are released in a shorter period of time owing to the exhaust operation initiated at a high temperature. This can be explained by referring to FIG. (a) illustrating the exhaust gas flow routes in the panel. The exhaust gas flow routes are categorized into four groups including the gas flow route between the separation walls 11, the gas flow route around the separation walls 11, the exhaust hole itself and the exhaust pipe 13. In studying the former two categories in which the height of the gas flow route is at most between 100 mm and 200 mm, all the gas flow coming from the flow route between the separation walls 11 is converged into the flow route around the separation walls 11, and the exhaust conductance of the gas flow route around the separation walls 11 is the lowest in the panel in which the distance between the

separation wall 11 and the sealing glass 14 is between 3 and 5 mm. Therefore, the exhaust operation with higher efficiency can be established by using the wider gas flow route around the separation wall 11.

In this embodiment, the exhaust operation is performed in the stats shown in FIG. 3 (b), and the overall state of the panel shows that the substrate glass is deflected due to the atmospheric pressure as shown in FIG. 6 (b). The back substrate 2 and the separation wall 11 contact to each other at the central part of the panel, and the clearance gap between them is formed by the sealing glass 14 working as a spacer around the sealing glass 14. As this gap defines a gas flow route around the separation wall 11 as an important structure determining the exhaust conductance level, the exhaust conductance can be increased by performing the exhaust operation before breaking down the sealing glass 14 as in this embodiment. Thus, the fact that the exhaust time is as short as 3.5 hours and the lighting voltage is low as shown in FIG. 5 comes from such a property that the gas can be easily exhausted.

In the plasma display panels, the gaseous impurities are spiked out from the structure components also by the plasma discharge during in the lighting other than the exhaust operation at a high temperature. By making the best use of this property and continuing the lighting operation in a definite period of time before shipping the products, the gaseous impurities which was not released by the extraction operation in a high temperature can be extracted from the structure component in order to light the panel stably with a low voltage, which is called aging and comes into wide use. FIG. 5 (5) shows the relation between the aging time and the lighting voltage studied for the panel manufactured with the exhausting time required for the lighting voltage to converge to a steady value (6 hours for the reference example and 3.5 hours for this embodiment) as shown in FIG. 5 (a). The aging time in the reference example is

required to be so long as 20 hours, but the aging time in this example is only ten hours. This result reflects straightforwardly the difference in the concentration of the gaseous impurities before aging between those two cases.

As apparent from those described above, the exhausting operation with higher efficiency can be performed without leakage at such a high temperature as not experienced ever, which enables to reduce greatly the overall time for manufacturing the panel including the aging process.

FIG. 7 shows the changes in the relative brightness in discharge operations measured for the panel formed by aging for 20 hours after applying the exhausting operation for 6 hours as a reference example, and the panel formed by aging for 10 hours after applying the exhausting operation in this embodiment, assumingthat the initial white brightness is normalized to 100%. The relative brightness in the reference example reduces by 27% after continuing the discharge operation for 10,000 hours, and in contrast, the relative brightness in this embodiment reduces by at most 20%. This result shows that, in the reference example, the inside of the panel is contaminated by the gaseous impurities are released from the sealing glass 14 over an extended time period even if the panel is finished by the aging process, and in contrast that, in this embodiment, as the sealing glass 14 has protruding portions having a curvature radius between 0.1 mm and 1mm and hence, its surface area is larger, the gaseous component can be extracted efficiently from the sealing glass 14 in the exhausting operation, and consequently, the amount of gas developed during the discharge operation can be reduced. Thus, if the sealing glass 14 is formed soas to have protruding portions having a curvature radius between 0.1 mm and 1mm viewed in thedirection from the display panel along the overall periphery in the internal space of the sealing glass 14, is can be concluded that an decrease in the brightness while lighting the panel for an extended

time period can be avoided. As the surface area at the protruding portions having a curvature radius less than 0.1mm or exceeding 1mm does not change too much and its brightness may undesirably decrease as much as the brightness for the reference example does. In addition, as apparent as described in the manufacturing method for the panels, it is allowed to manufacture the gas discharge type display panel without using the pressurizing clips. In such a method that only four clips for positioning shown in FIG. 3 are used for fixing temporarily the panel, a couple of 42-inch AC-type plasma display panels formed together to be adjacent to each other on a common large-sized substrate are successfully sealed. As the boundary portion between two panels can not be fully pressurized only by the conventional clips 16 for pressurizing the frit, and hence the resultant display panel is easily broken due tocamber or distortion, the yield rate for sealing is as low as 10% or less, and the color mixture is found in the portions to which the pressurization was not fully applied, and thus, we could not obtain 42-inch sized panels satisfyingpractically its performance requirements. In contrast, by using the sealing method of this embodiment, we could obtain panels with their yield rate more than 90% providing the same satisfactory performance level as the panels formed by sealing individual panels separately. In case of applying the sealing method of this embodiment, plural large-sized panels can be sealed all at once with higher yield rate, which is valid for achieving a higher productivity anddownsizing the manufacturing cost. As for the bonding method for the exhaust pipe 13, there is such a method as the upper face of the flare work part of the exhaust pipe 13 and the back glass substrate are bonded by the sealing glass 14 (paste or preform), which is used for mass-production and becomes popular. It may be allowed to apply this method to this case if some problems on leakage while reducing the pressure in the sealing operation could be solved by making the exhaust pipe 13 shaped so as to enable a firm contact between the

exhaust pipe 13 and the back face substrate 2 and such.

(Embodiment 2)

In the second embodiment of the present invention, a plasma display panel is formed by using the different exhaust gas temperature from the first embodiment. FIG. 8 shows the temperature profile for the sealing and exhausting processes.

Another plasma display panel is formed by the procedure for initiating the exhausting operation after holding the temperature at 430°C for 30 minutes and cooling down to the room temperature without keeping the temperature constant while reducing the temperature, and the cross section of the resultant plasma display panel developed in the direction perpendicular to the back side substrate 2 is observed. FIG. 9 illustrates diagrammaticallythe state of the sealing glass 14.

For the panel formed with 450°C among the panels formed by varying the exhaust gas temperature, the viscosity of the sealing glass 14 reduces too much and there found a leakage in the glass for sealing the substrate. In case of sealing the substrate with amorphous glass, it is not preferable because the leakage may occur when exhausting the gas at the temperature higher than the working point. There is no leakage for the panel formed with 455°C at the same temperature level as above. This can be interpreted by considering the special distribution of the filler. The filler is distributed uniformly in the cross section shown in FIG. 4 (b) to which the conventional sealing method is applied. However, in case of this embodiment in which the exhaust operation is applied to the sealing glass 14 having a lower viscosity, that is, at the sealing temperature, the filler is pulled toward the discharge space as shownin FIG. 9, and then the filler concentration at the discharge space becomes higher. The liquidity at the discharge space herewith decreases, and then the leakage is blocked, and consequently the exhaust operation can be performed even at the relatively higher temperature, 445°C,

near the working point. The filler distribution is state quantitatively as shown in FIG. 9, in which the average filler concentration at the portion extending in 100m from the end part facing to the discharge space is 10% or more higher than the other portions. Though the extreme concentration of the filler at any part makes its thermal expansion smaller and may cause unfavorably cracks and/or distortion due to the difference in the thermal expansion between this part and the substrate, there is no problem in fact because the distortion can be released by the protruding portions formed as shown in FIG. 1.

Exceptionally, if the extreme concentration of the filler occurs over the portions extending in more than 100 m, it is unfavorable because there may occurs cracks and/or distortion due to the difference in the thermal expansion between those portions and the substrate.

If the increase in the average concentration of the filler at the portion extending in 100 m from the end part facing to the discharge space is 10% or less, the effect given to the liquidity of the sealing glass 14 is small and the sealing glass 14 moves toward the inside space at the relatively higher temperature near the working point, and thus, as this makes the exhaust route narrower, it is preferable to control the increase in the average concentration of the filler within 10%.

FIG. 10 (a) shows the result of studying the lighting voltage by changing the exhaust time denoted by Xh shown in FIG. 3. FIG. 10 (b) shows the relation between the aging time and the lighting voltage. FIG. 10 also includes the result for the caseof the exhausting operation at 350°C which was described in the first embodiment. As shown in FIG. 10 (a), the longer the exhausting operation continues at a higher temperature, the more the concentration of the remaining gaseous impurities reduces and the lower the lighting voltage can be maintained. As for the exhausting time, though

the exhausting conductance of the panel is not high when the temperature is kept constant after breaking down the sealing glass 14, the required exhausting time can be made shorter at the higher temperature because the gaseous impurities are removed more quickly at the higher temperature. It is found to be apparent that there occurs no leakage by adjusting the exhausting time even if the temperature higher than the softening point s kept for 9 hours.

Next, FIG. 10 (b) shows that the aging operation can be performed in a shorter period of time if the exhausting operation is applied at a higher temperature, and that the lighting voltage can be made lower. This reflects the fact that the concentration of the remaining gaseous impurities for the panel in which the exhausting operation is applied at a higher temperature reaches a lower level before the aging operation begins, and that the amount of the gaseous impurities to be removed at the aging operation can be reduced. As described above, what we can obtain is such a gas discharge type display panel as the exhausting operation can be applied highly efficiently by exhausting at a higher temperature and the concentration of the remaining gaseous impurities can be made lower.

(Embodiment 3)

In the third embodiment of the present invention, a plasma dispay panel is manufactured by using a crystalline glass frit (with the softening point at 390C, the crystallization peak temperature at 430°C and a filler included) for the sealing glass 14 and an amorphous glass frit (with the softening point at 390°C, the working point at 430°C and a filler included) for the seal frit bonding between the exhaust pipe 13 and the back substrate 2, and by using the exhaust pipe 13 having such a sectional form as shown in FIG. 11. This manufacturing method is the same as in the embodiment 1, and uses two temperature profiles shown in FIG 3including the case (a) in which the first

heat reserving process continues for 5 minutes and the second heat reserving process continues for 3.5 hours, and the case (b) in which the first heat reserving process continues for 10 minutes and the second heat reservingprocess continues for 3.5 hours.

The exhausting process can be applied with no problem by using the exhaust pipe having a larger connecting area as shown in FIG. 11 (b). Even with the exhaust pipe having a smaller connecting area as shown in FIG. 11 (a), the exhausting process can be applied properly by using crystalline glass for sealing the exhaust pipe 13 as in the embodiments 1 and 2 and using amorphous glass for sealing the substrates. This means that if the glass material used for sealing the exhaust pipe 13 has a heat resistance higher than the sealing glass 14 for the substrates, the viscosity of the glass material for sealing the exhaust pipe 13 is maintained to be a certain level and there occurs no leakage even if the viscosity of the sealing glass 14 for the substrates might decrease at the sealing temperature. In case that both of those glass materials have an identical viscosity, there may occur leakage if the bonding area between the exhaust pipe 13 and the substrates is not large enough. No matter what shape is used for the exhaust pipe 13, materials with higher heat resistance arepreferably used for the glass for sealing the exhaust pipe 13 rather than for the sealing glass 14 for the substrates. Though it is allowed to use amorphous glass materials for both glasses in order to define a difference in their characteristic temperature, too large difference in their characteristic temperature can not be defined because those sealing glasses are required ultimately to be sealed, which leads to a difficulty in selecting the glass material. By means of using a crystalline glass for sealing the exhaust pipe 13 and using an amorphous glass for sealing the substrates, it will be appreciated that their characteristic temperature could not be limited to each other, and that those can be heated up to the temperature higher than the sealing temperature after sealing, which concludes that this combination of

glass materials is most preferable.

A plasma display panel is formed at the above mentioned two temperature profiles and by using the exhaust pipe 13 as shown in FIG. 11 (b), and thethickness of the sealing glass 14 after the sealing operation is measured and evaluated. It is found that the panel (a) is broken down to the height approximately equivalent to the height of the separation wall 11, and that the panel (b) is not fully broken down. This shows that the sealing glass 14 gets harden as it crystallization goes to a certain degree and that it can not be fully broken down to a desired height. As in thisembodiment, by means of using amorphous glass material for the sealing glass 14, the freedom in the temperature profiles can be advantageously enhanced.

(Embodiment 4)

In the forth embodiment of the present invention, a plasma display panel is manufactured by using a crystalline glass frit (made with V_2O_5-P_2O_5 system, and having the softening point at 390°C, the crystallization peak temperature at 430°C and a filler included) for the sealing glass 14 and an amorphous glass frit (made with PbO-B_2O_3 system and having the softening point at 390°C, the crystallization peak temperature at 430°C and a filler included) for the seal frit bonding between the exhaust pipe 13 and the back substrate 2. As shown in FIG. 12, this panel has an additional separation wall 18 with 1mm width along the overall periphery at the inside (within 2mm) of the sealing glass 14. The fabrication method for this panel is almost the same as the panel in the first embodiment except adding the separation wall 18, and the temperature profile used for the sealing and exhausting processes is shown in FIG. 13.

As a result, the gas inside the panel having the structure shown in FIG. 12 can be fully exhausted. This is because the sealing glass can be blocked by the separation wall 18 when the sealing glass is pulled inside the discharge space by theexhausting

operation, and thus, the width of the sealing glass can be made uniform and the occurrence of the leak path can be prevented. This separation wall 18 gives such an effect that, even if the protruding portion formed at the discharge space by the exhausting operation may be removed by the exhausting operation further continued, this protruding portion may not extend into the inside the discharge space and block the exhausting route, and may not remain between the separation wall 18 and the front substrate 1. Although the separation wall 18 is formed inside the sealing glass 14 in this embodiment, the same effect can be obtained by forming a sealing glass having a higher softening point as a "levee" inside the sealing glass 14.

(Embodiment 5)

In the fifth embodiment of the present invention, a plasma display panel is manufactured by forming separation walls 11 extending in the vertical and horizontal directions as shown in FIG. 14, having the same material structure as the first embodiment. The manufacturing method for the frontsubstrate 1 and the back substrate 2 and the number of pixels of the panel are the same as those in the first embodiment. Only the sealing and exhausting processes for this embodiment are described below. The temperature profile used for the sealing and exhausting processes is shown in FIG 15.

(1) At first, the substrates are aligned and fixed temporarily and the exhaust tube 13 is fixed in the same manner as the first embodiment, and thecomposite substrates are installed in the furnace and the exhaust head is made connected to the exhaust pipe 13. The temperature is made increase up to the sealing temperature 430°C in this configuration. Though the sealing glass 14 gets soft and contacts to the front substrate 1 and the periphery of the substrate is sealed hermetically, the clearance gap between the substrates does not reach the height of the separation wall 11 because the pressurization

clip does not exist. On the other hand, the seal frit 15 used for bonding the exhaust tube 13 and crystallization in the back glass substrate is not fullydeveloped at this step, and its viscosity remains low.

(2) After the sealing temperature reaches 430°C, its temperature is kept for 30 minutes. During this period, the seal frit 15 establishes its crystallization and the exhaust pipe 13 is bonded firmly to the back substrate 2. The temperature is made increase up to 400°C in this state.

(3) After the temperature reaches 400°C, the exhausting operation is initiated. The sealing glass 14 stays in such a state that it has higher viscosity and is less apt to be broken down than in the temperature 430°C. Thus, the exhausting operation is applied at the state that the clearance gap between the front substrate 1 and the back substrate 2 is large. As the exhausting operation for the center part of the panel can not performed efficiently due to the deflection of the substrate glass as shown in FIG. 6 (b), the exhausting operation is applied again after introducing nitrogen gas in the process, fixing the deflection and thus facilitating the removal of the gaseous impurities.

The temperature reaches 430°C while continuing the exhausting operation after 3 hours passed since the exhausting operation begins.

(4) Along with the increase in the temperature, the sealing glass 14 gets fort and the sealing glass 14 is broken down due to the pressure difference between the inside and outside of the panel. After completing the breaking-down of the panel, Ne gas including Xe gas by 3% volume at the room temperature is made introduced into the discharge space through the exhaust pipe 13 at 700Torr so that its pressure may reach 300Torr, and the temperature is made decrease down to the room temperature. After cooling down, the exhaust pipe 13 is burned off by heating locally, and finally, a gas discharge type display device is established.

As the exhausting operation is applied after breaking down the sealing glass in the conventional panel manufacturing method, the gas discharge type display panel in which its discharge space is separated into isolated cells by the separation walls 11 as shown in FIG. 14. In this embodiment, as the exhausting operation can be applied at the state that the clearance gap between the front substrate 1 and the back substrate 2 is kept large enough, and the removal of the gaseous impurities staying in the internal space can be facilitated by introducing inert gas such as nitrogen gas, the exhausting operation and the removal of the gaseous impurities can be performed highly efficiently.

The cell structure shown in FIG. 14 contributes to an increase in the effective area for applying fluorescent materials on it, and thus, a brightness 500cd/m2 can be attained in comparison with the brightness 350cd/m2 in the cell structure shown in FIG. 6.

(Embodiment 6)

In the sixth embodiment of the present invention, in the similar manner to the fifth embodiment, plasma display panel is manufactured by forming separation walls 11 extending in the vertical and horizontal directions as shown in FIG. 14 and sealing doubly the substrates with two kinds of sealing glass having an individual softening point different with each other. As for the sealing glass outside, what is used is a low softening-point amorphous seal frit 20 which has the softening point at 390°C and the working point 450°C, and as for the sealing glass inside what is used is a low softening-point amorphous seal frit 19 which has the softening point at 350°C and the working point 410°C. an crystalline glass frit 15 the softening point at 350°C, the crystallization peak temperature at 400°C for bonding between the exhaust pipe. Those seal frits include filler materials.

The manufacturing method of the front substrate 1 and the back substrate 2 and

their number of pixels are the same as those in the first embodiment except that the seal frit s are formed doubly. The sealing andexhausting operations are described below. The temperature profile used in the sealing and exhausting operations is shown in FIG. 16. FIG. 17 shows the stepwise change in the state of the panel sealed in two steps.

(1) At first, the substrates are aligned and fixed temporarily and the exhaust tube 13 is fixed in the same manner as the first embodiment, and thecomposite substrates are installed in the furnace and the exhaust head is made connected to the exhaust pipe 13. The temperature is made increase up to the sealing temperature 350°C in this configuration. The crystalline glass frit used for bonding the exhaust pipe 13 and the back glass substrate stays in the state that its viscosity is low.

(2) After the sealing temperature reaches 350°C, its temperature is kept for 30 minutes. The state at this step is shown in FIG. 17 (a). The low softening-point seal frit 20 gets soft and contacts to the front substrate 1. Although the periphery of the substrate is sealed tightly, the clearance gap between the substrates does not reach the height of the separation wall 11 because there is no pressurization clip. While keeping the temperature constant for 30 minutes, The crystallineglass 15 experiences a reduction of the grain size of the glass, a fixation with the substrate glass and slight crystallization, and the exhaust pipe 13 is fixed firmly to the back glass substrate. The exhausting operation (exhausting roughly) is initiated at this step.

(3) In the process for increasing the temperature up to 430°C, although the low softening-point seal frit 20 is broken down, the high softening-point seal frit 19 does not get soft much and prevents the substrates from contacting firmly to each other by acting as a spacer shown in FIG. 17 (b). On the other hand, the crystalline glass used for bonding the exhaust pipe 13 gradually develops its crystallization, and thus, the bonding between the exhaust pipe 13 and the back glass is firmly established.

(4) As the temperature reaches 430°C, the high softening-point seal frit 19 begins to get soft and contacts to the front substrate 1, and the sealing of the panel can be established only by the high softening-point seal frit 19. The exhausting operation is further made continue up to higher vacuum at this step.

(5) In the process for keeping the temperature 430°C constantly, both the high softening-point seal frit 19 and the low softening-point seal frit 20 are broken by the pressure difference between the inside and outside of the panel. The state at this step is shown in FIG. 17 (c). After cooling down to the room temperature, a discharge gas is made introduced into the discharge space through the exhaust pipe 13 so that its pressure may reach 300Torr, and the exhaust pipe 13 is burned off by heating locally, and finally, a gas discharge type display device is established.

Although there may occur a leakage from the seal frit 15 used for bonding the exhaust pipe 13 with the exhausting operation at 350°C, the exhausting operation can be applied successfully by keeping its internal pressure in a low degree of vacuum.. In case that a single kind of seal frit is used as in the first embodiment, it is difficult to determine the exhausting temperature properly and have higher flexibility in selecting the temperature, because it is desirable to apply the exhausting operation without making the seal frit get soft and at a higher temperature. In this embodiment, depending on the combination of characteristic temperatures for two or more kinds of seal frits, various temperature profiles can be developed. In this embodiment, as the exhausting operation can be initiated even at the process for increasing the temperature, and the exhausting operation can continue at the sealing temperature for the high softening-point seal frit, the exhausting operation can be applicable with extremely higher efficiency.

As shown in FIG. 10 (b), though the aging operation is required approximately

for 6 hours even by applying the exhausting operation at 430°C for the single-layered sealing configuration, there found no difference in the lighting voltage after applying the aging operation in this embodiment, which reflects the fact that the concentration of the gaseous impurities at the panel is low. In the sealing and exhausting method using two kinds of seal frits as in this embodiment, it is allowed that either of the high softening-point glass and the low softening-point glass may be positioned inside, and the multiple sealing configuration may contribute to no furtherextension of its essential effect.

It is possible to manufacture in the shortest time and with higher operability such a plasma display panel as having a high mechanical strength and a highreliability, enabled to be driven with lower voltage, providing a higherbrightness and sized in a large dimension.